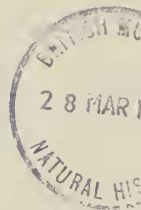


INTRODUCTION TO
THE MIOCENE MAMMAL FAUNAS
OF GEBEL ZELTEN, LIBYA



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INTRODUCTION TO THE MIOCENE MAMMAL FAUNAS OF GEBEL ZELTEN, LIBYA

By R. J. G. SAVAGE & W. R. HAMILTON

ABSTRACT

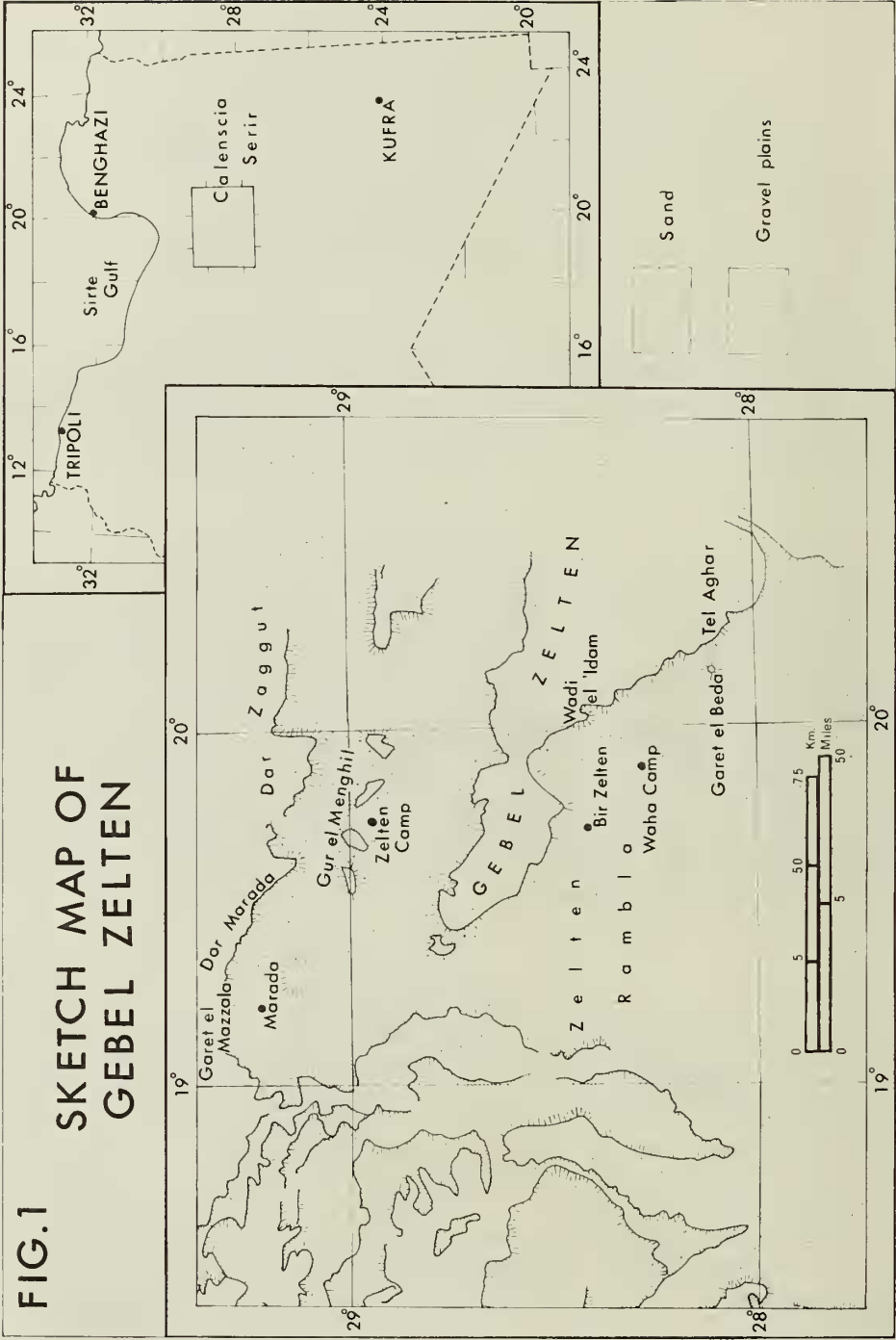
AN account is given of the occurrence of Miocene mammals at Gebel Zelten, central Libya. The geographical and geological settings are summarized, the history of the exploratory work reviewed, the composition of the fauna and flora is discussed, and the probable environment and age of the succession are assessed.

GEOGRAPHY

Gebel Zelten lies about 200 km south of the Gulf of Sirte (Fig. 1.). It consists of an elongate mesa which runs northwest—southeast, for about 140 km at $19^{\circ} 30' - 20^{\circ} 30' \text{ E.}$, $28^{\circ} - 29' \text{ N.}$ The Esso Petroleum Zelten camp lies to the north of the gebel and the Oasis Waha camp lies to the south, the road joining these camps crosses the gebel at its narrowest point where it is only 8 km wide. In the west the gebel rises 40–60 m above the Zelten Rambla (sand sea); it dips gently to the east and blends with the Calenscio Serir (gravel plain) at its eastern end. The plateau is capped by a marine sandstone which is early Miocene in age and the edges are dissected by steep-walled wadis up to 3 km in length. It is in these wadis that many of the vertebrate remains are found, though some of the sites are on washout areas from the wadis.

HISTORY OF DISCOVERY

The first geological party to see the area was the Italian Scientific mission to Kufra in 1931, under the leadership of Professor Ardito Desio. Desio (1935) gave the name Marada Series to the succession of the Dor el Marada, 50 km northwest of Gebel Zelten. Desio's type section at Garet el Mazzala is about 80 metres thick and comprises mainly shales with interbedded sands and limestones; he recorded gypsum layers and a fauna of marine invertebrates and fish. The Italian route to Kufra, (still marked by fusti posts), lay along the western borders of the Gebel Zelten. On the basis of the shelly fauna Desio considered the Marada Series to be Langhanian (= Burdigalian) and Helvetian. Desio was probably only able to spend a very short time at Gebel Zelten and was unfortunate not to find any higher vertebrates. The two places where the fusti posts come closest to the



escarpment, (at Bir Zelten and Tel Aghar), are barren of fossils, not being near any of the river channels. Desio did however suggest the Zelten sandstone succession was in part contemporary with the Marada succession and equivalent to Aquitanian-Langhian transition.

In 1957 Savage, as a member of the British Ennedi Expedition, passed east of Gebel Zelten across the Calenscio Serir en route to Kufra, but no outcrops were seen. With the exploration for petroleum in the late 1950's, prospecting gradually moved south from the coastal belt. In 1960 M. Magnier, of the *Compagnie des Petroles Total Libye*, explored the Gebel Zelten and found the first mammalian fossils. In December 1960 Professor C. Arambourg visited the north side of Gebel Zelten with M. Magnier and spent 10 days collecting surface finds (Arambourg & Magnier 1961, Magnier 1962, 1967). Arambourg (1961a & b, 1963) later described some of the species recovered and now housed in the *Museum d'Histoire Naturelle*, Paris. During the following three years prospecting intensified, concessions were allocated and oil production commenced. Gebel Zelten falls into two concessions divided along the parallel $28^{\circ} 30'$ into a northern part in the Esso concession 6, and a southern part in Oasis concession 59. Colley (1964) summarized the regional setting of the geology.

In 1963 Dr R. C. Selley of Imperial College, University of London, commenced a series of visits to the Marada and Zelten regions to study the stratigraphical succession and the sedimentary history (Selley 1966, 1967 and 1969). In 1965 Dr H. Doust also of Imperial College commenced a study of the palaeoenvironment using especially invertebrate and trace fossils (Doust 1968).

The finding of bones by oil prospecting geologists aroused interest and invited detailed exploration. Three expeditions under the leadership of Dr R. J. G. Savage from the University of Bristol have concentrated on the vertebrate faunas of the Gebel Zelten area. In 1964 Savage accompanied by Mr M. E. White spent two months at Oasis Waha camp exploring the southern half of the Gebel Zelten. In 1966 Savage accompanied by Dr S. W. Taylor spent a month at the Esso Zelten camp exploring the northern half of the Gebel. In 1967 Savage accompanied by Dr J. M. Harris visited the northern and southern sides of the gebel and made further collections. In 1968 Savage accompanied by Dr. W. R. Hamilton briefly visited the area on their way south and made some additions to the collections. Preliminary reports are to be found in Savage & White (1965), Savage in Selley (1969) and Savage (1971), and the first monograph on ruminants is by Hamilton (1972).

GEOLOGY

The following account of the geology is taken largely from Selley (1966, 1969). In view of the detailed work of Selley no stratigraphic work was undertaken by the Bristol parties. The vertebrate collecting is regarded as complementary to the work of Selley on the sediments and of Doust on the invertebrate fauna.

During the late Mesozoic and Tertiary a series of shelves and basins developed on the northern edge of the Saharan shield in the Tethyan foredeep. The Sirte Basin was one of these basins which gradually became infilled as subsidence waned

and the sea retreated northward during the Tertiary. The centre was infilled with shales while around the rim carbonate sediments were deposited. The marginal limestones are mainly of detrital organic origin and often dolomitized; fossils abound, especially oysters, corals, bryozoans, echinoids and foraminifera. Interbedded with the limestones are unfossiliferous shales, often gypsiferous. The limestones and shales are locally replaced shoreward by sandstones as in the region of Gebel Zelten. The majority of the oil and gas reserves are found in the marginal facies of the basin.

Selley has substituted the term Marada Formation for Desio's Marada Series and has included the Zelten succession in the formation. Selley (1966) recognised five major facies each with characteristic lithology, environment and fauna (Table I). Selley envisaged a series of offshore bars with lagoons behind, into which issued rivers depositing fluviatile sediments (Fig. 2). The reconstruction shows a major river flowing north through the Gebel Zelten area with distributaries on the north side of the escarpment. Selley produced a wealth of detailed quantitative analyses to support his interpretations, and compared the regime to that of the present day coast of Texas and the Trucial coast.

Doust (in Selley 1969) has cast doubt on the nature of the limestone reefs, suggesting the limestones formed as submarine banks, thus leaving the sea to invade the 'lagoons' with restricted circulation on intertidal flats. The nature of the fluviatile and estuarine environments is unquestioned.

Palaeontology

Doust (1968) has described the marine faunas in detail. Ichnofossils abound and the limestones are particularly rich in shelly faunas. In the broken ground of Gur el Menghil, between Dor Zaggut and Gebel Zelten, Doust was able to correlate beds on the occurrence of two marker bands, both close together near the middle of the section. The lower band contains abundant remains of the bryozoan *Idmonea fenestrata* Busk and two metres above is a band rich in the echinoid *Echinolampas*. These bands can be traced south into Gebel Zelten, where on average the invertebrate fossils are less abundant and the only common and widespread fossil is the oyster *Crassostrea gryphoides* (Schlotheim).

Apart from calcareous algae, plant fossils are very rare. Samples of matrix and coprolites were examined by Dr K. C. Allen of Bristol and Dr. D. K. Ferguson of Utrecht but no undoubted pollen was found. A few leaf fragments have been found, some of which are probably bog-myrtle (*Myrica integerrima*). The only fruit found were ground cucumbers (*Cucumeria*).

Silicified wood is virtually ubiquitous, not only in the Gebel Zelten, but throughout the Sahara, more or less regardless of the stratigraphic age of the beds where it is found, be they Mesozoic or Tertiary, marine or non-marine. The wood tends to be commonly in association with arenaceous facies. In a few sites wood was found to have borings; the holes are around half a centimetre in diameter. They could have been made by the marine worm *Teredo*, or alternatively they could be due to a tropical insect. In fifteen years of desert travel, Savage has rarely seen wood which is indubitably and stratigraphically *in situ*. In the instances where wood has

TABLE I

Summary of facies parameters (after Selley 1969)

Facies	Lithology	Distribution	Sedimentary structures	Fauna	Palaeocurrents	Supposed environment
1. Detrital limestones	Bioclastic calcarenites, rare calcirudites and calcilutites	Predominate in north	Massive, flat-bedded or cross-bedded, often bioturbated	Mainly marine	Bi-modal, major mode directed southwards (on-shore)	Off-shore bars and barrier beaches
2. Laminated shales	Calcareous shales and calcilutites		Laminated or massive	Local oyster reefs	None	Lagoonal
3. Interlaminated shales and sandstone	Shales & silts; rare fine sands		Interlamination, small-scale cross-stratification and bioturbation. Channeling. Lignites.	Mixed marine and continental	None	Intertidal
4. Cross-bedded sands and shales	Coarse sands > silts and shales	Predominate in south	Sands: large-scale cross-stratification. Silts & shales: laminated or rippled. Lignites and palaeosols.	Continental vertebrates & plant remains	Unimodal, northwards (off-shore)	Fluvial
5. Calcareous sandstone channels	Coarse calcareous sandstones and sandy limestones	N-S trending shoe-strings	Channels, large-scale cross-stratification, quicksand structures	Mixed marine and continental	Bi-modal, major mode directed northwards (off-shore)	Estuarine channels

been found in bedded rock, it was quite different from the silicified wood of surface occurrence. The stratified wood is brittle and in small pieces, is largely or completely unsilicified, and if silicified the replacement is usually chalcedony or milky opal. We are definitely of the opinion that the vast majority of fossil wood found in the Sahara, including the Gebel Zelten area, is not contemporary with the sediments and represents a Pleistocene flora. From the artifacts and mammals distributed across the Sahara, we know that in Pleistocene times the climate included tropical and Savannah regimes. The development of laterites, caliches and silification are all in our mind associated with tropical, even monsoon conditions. The association of the three features can be seen in the Australian deserts today. Laterites and silicification are well known from the Deccan of India and from the Tertiary inter-basaltic areas of Britain. In Gebel Zelten the wood is not sufficiently well preserved to permit specific identification, but dicotyledonous trees and palms are recognizable. All this wood however must be regarded as post-Miocene and therefore of no help in the palaeoenvironmental interpretation of the Zelten facies.

The majority of vertebrates are mammals, but there is also a representative selection of lower vertebrates. Fish remains are not infrequent, usually vertebrae and broken bones, with only occasionally teeth; sites 6405, 6416 and 6423 have

DEPOSITIONAL ENVIRONMENTS GEOMORPHOLOGY

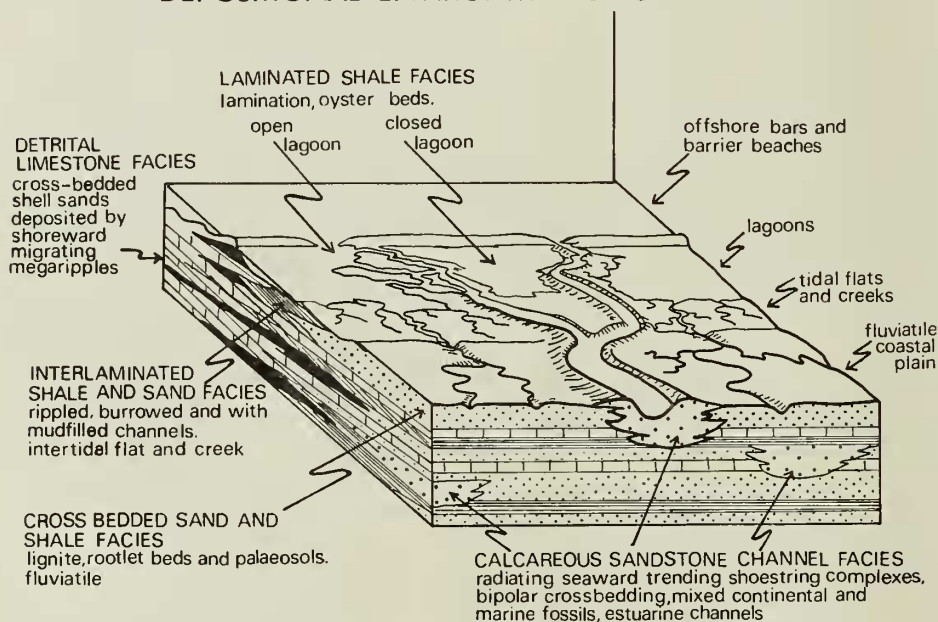


FIG. 2. Block diagram illustrating the supposed origin of the Miocene shore-line of the Sirte basin. (After Selley 1969, Text-fig. 17. Reproduced by courtesy of Dr R. C. Selley and the Geological Society of London.)

TABLE 2

Vertebrate Fauna of Gebel Zelten

<i>Fish</i>	
Elasmobranchii	<i>Odontaspis acutissima</i> Agassiz <i>Carcharodon</i> sp. <i>Hemipristis serra</i> Agassiz <i>Pristis</i> sp. <i>Myliobatis</i> sp.
Actinopterygii	<i>Lates</i> sp. Silurid
<i>Reptiles</i>	
Crocodylidae	<i>Tomistoma dowsoni</i> Fourtau <i>Euthecodon</i> sp. <i>Crocodylus</i> sp.
Chelonia	<i>Podocnemis aegyptica</i> Andrews Testudinid indet. Trionychid indet.
<i>Birds</i>	
Aepyornithidae	? <i>Eremopezus</i> sp.
<i>Mammals</i>	
Sirenia	gen. nov.
Proboscidea	<i>Mastodon angustidens</i> Cuvier <i>Mastodon pygmaeus</i> Arambourg <i>Prodeinotherium hobleyi</i> (Andrews) Saghatheriine; cf. <i>Prohyrax</i>
Hyracoidea	
Perissodactyla	
Rhinocerotidae	<i>Brachypotherium snowi</i> (Fourtau) <i>Aceratherium</i> sp.
<i>Artiodactyla</i>	
Anthracotheriidae	<i>Brachyodus</i> sp. <i>Hyoboops africanus</i> (Andrews) <i>Hyoboops moneyi</i> (Fourtau)
Suidae	<i>Diamantohyus africanus</i> Stromer <i>Bunolistriodon massai</i> Arambourg <i>Bunolistriodon</i> sp. nov. <i>Listriodon</i> sp. indet.
Giraffidae	<i>Zarafa zeltani</i> Hamilton
Sivatheriidae	<i>Prolibytherium magnieri</i> Arambourg
Tragulidae	<i>Dorcatherium libiensis</i> Hamilton
Palaeomerycidae	<i>Canthumeryx sirtensis</i> Hamilton <i>Palaeomeryx</i> sp. Palaeomerycid indet.
Bovidae	<i>Gazella</i> sp. <i>Protragocerus</i> sp. <i>Eotragus</i> sp.
<i>Creodonta</i>	
Hyaeodontidae	<i>Megistotherium osteothlastes</i> Savage <i>Anasinopa</i> sp.
<i>Carnivora</i>	
Canidae	<i>Afrocyon buroletti</i> Arambourg Amphicyonine indet.
Felidae	cf. <i>Metailurus</i>

yielded abundant fish; most of the identifiable remains from site 6416 are silurid. Amphibia are unknown and birds extremely rare; only three indubitable records stand. Arambourg's record (1961b) in the Gur el Menghil of an aepyornithid, and two ratite bones from sites 6404 and 6407. There are abundant and ubiquitous crocodile and chelonian remains, usually very fragmentary, with six taxa distinguishable. The profusion of large individuals of crocodiles suggests warm waters and plentiful food supply. The mammals are still being studied and the provisional list of species is to be found in the accompanying Table 2.

PRESERVATION

The majority of vertebrate remains are preserved in unconsolidated sands. Articulated skeletons are unknown and only a few partially associated skeletons are known. Relatively complete skulls, mandibles and bones are frequently found and show no signs of rolling or transport before burial. The preservation of bone is highly variable and three types of preservation are known, with sometimes gradations between. Bone found fully exposed on the surface is usually coated with desert varnish and well preserved, though the large temperature range causes the teeth to split and break up. Buried bone is usually similar to surface bone but without the varnish; it tends to be more brittle, but when carefully treated with bonding plastics can be readily recovered. A third category of bone is so brittle that it virtually disintegrates to dust on touching. Harris (1969) suggested two possible explanations for this phenomenon: a long period of weathering before burial and impregnation with salts in process of formation of subsurface salt layers.

ENVIRONMENT

From the sedimentary evidence of Gebel Zelten, Selley (1969) has established that a river system flowed northward across intertidal flats and compared the physical conditions to those of Texas coast and Trucial coast at present time. From the evidence of the shelly marine fauna, Doust (1968) has envisaged an environment most closely related to that of the tropical Atlantic. The evidence quoted by various authors on the basis of silicified wood is not accepted on grounds that the wood is not contemporary with the deposit. The aquatic vertebrates comprise fish, reptiles and a sea-cow. The fish are not abundant and mostly sharks and rays, implying marine or brackish waters. Crocodiles and turtles are ubiquitous, especially in the fluviatile facies; some of the crocodiles can be estimated to have been 8 metres long. Such large crocodiles and turtles would suggest tropical temperatures. Amongst the terrestrial mammals mastodon and *Deinotherium* were about equally abundant, with giraffes and anthracotheres as the dominant medium sized herbivores. Rhinoceroses and pigs were also present. Carnivores are rare, but include a gigantic hyaenodont. Interpretation of the vertebrate evidence suggests a forested belt along the river and savannah in the hinterland, similar to present day conditions along the banks of the Omo river as it flows into Lake Rudolf.

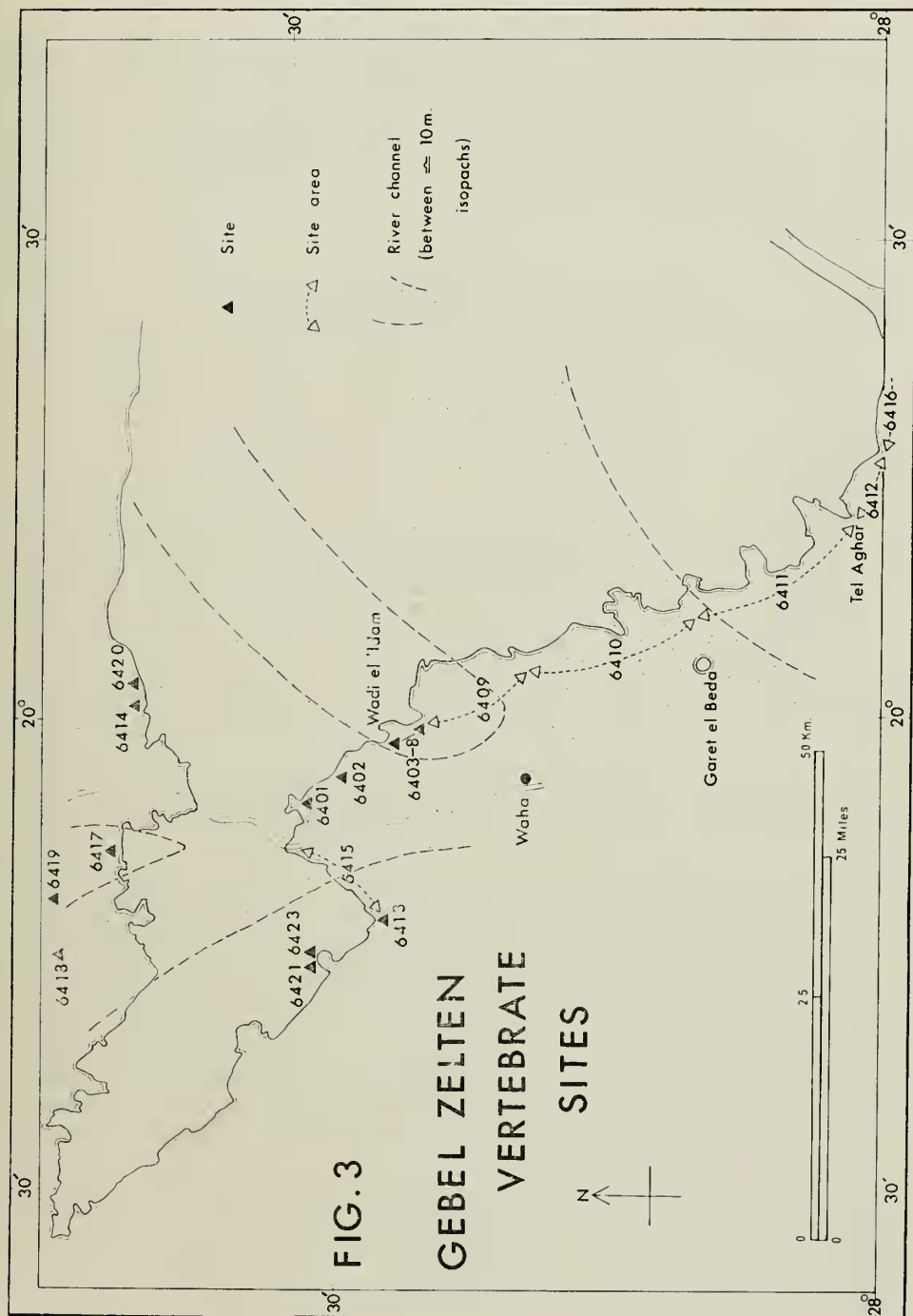


Fig. 3 shows the relationship of the palaeogeography to the distribution of the vertebrate sites. The sites vary in size and yield. There are no pockets of bone concentration; sites vary from 1 to 10 acres (0.5-5 Hectares) and the yield ranges from a few specimens to over a hundred. There are four groups of sites which have accounted for about 85% of the specimens; these are shown in Table 3 as groups I, III, V and VII. Bones are found throughout the succession, but there tend to be levels of concentration.

TABLE 3
Distribution of vertebrate stocks in Gebel Zelten

GROUP	I	II	III	IV	V	VI	VII
	6417	6420	6421	6401	6403	6409	6412
Sites	6418	6414	6423	6402	6408	6410	6416
Coprolites	A	r	A	r	r	A	A
Fish	r	r	r	r	A	r	r
Chelonian	r	r	r	r	r	r	r
Crocodyle	A	A	A	r	VA	A	A
Sirenian	VA	r	r				
Bird		r	r		r		r
Mastodon	A	A	A	r	A	A	VA
Deinothera	A	r	r	r	A	r	r
Rhinocerotid	r	r	VA	r	r	r	A
Anthracothere		r	r	r	r	A	VA
Suid		r	r	r	r	r	A
Giraffoid	r	r	r	r	VA	r	VA
Bovid		r	A	r	A	r	A
Carnivore		r	r		r	r	A

r = 1-10 specimens; A = 11-20 specimens; VA = more than 20 specimens.

These are found near the base of the succession in Group III sites, near the middle of the succession in Group V sites, and high in the succession in Group VII sites. In Group I sites fossils are found on the gravel plain. At sites in Group III and VII, fossils are found on the outwash from the gebel and may in some cases be redeposited there in recent times. Group I sites are on the intertidal flats; they have an abundance of sirenian remains, including three partial skeletons. Deinotheres are also surprisingly abundant, with three skulls found in close proximity at site 6418. Site 6417 has yielded only a few fragments. Group II sites are close to the northern face of the escarpment and in the outflow of estuarine channels. Some good individual specimens came from these sites, including a giraffid skull. Remains of 12 mastodon skulls were found in close proximity, but all were too weathered to collect. In Group III sites the species are varied and reasonably plentiful, but only rhinocerotids are very abundant. The sites fringe a major estuarine channel and represent accumulation on fluvial banks and flood plains. The three sites in Group IV are within the estuarine channels and their yield is very low. In Group V are a series of sites grouped round an embayment in the gebel, which have a rich

yield of many taxa, in particular giraffids. The wealth of bones in this area prompted the name Wadi el 'Idam. The sites in Group VI stretch for some 30 miles along the escarpment but have yielded relatively few specimens.

Group VII sites, occupy a stretch of escarpment about 11 miles long. Since bones all occur at a similar level high in the succession, there is no reason to further differentiate the sites. The fossil yield is enormous, almost as many specimens as found in groups III and V together. Deinotheres are the only terrestrial mammals which are not abundant, although the most complete mandible was found here. Mastodons, anthracotheres, and giraffes are all very abundant. The sites are the most remote from the sea; no marine fish or sirenians were recorded, and the region may represent fresh-water ponding beside which mammals frequently gathered. With the dying out of the gebel to the south nothing further can be traced.

AGE

All the evidence for dating the deposits is fairly consistent and taken together gives a reasonable result.

The Marada Formation at Marada rests on the Grier Bu Hascisc Formation, a marine sequence with *Nummulites intermedius fitcheli*, which is characteristic of Rupelian age in North African sequences. The Dor Zaggut sections of the Marada Formation contain shelly limestones with *Borelis melo* and *Borelis melo curdica*, the latter being characteristic of Burdigalian age in North Africa and the Middle East. Less reliable but consistent evidence comes from the shelly fauna, which Desio (1935) considered Burdigalian-Helvetian in Garet el Mazzala and slightly earlier, Aquitanian-Burdigalian in Gebel Zelten. The Marada Formation fauna is closely comparable with that of the Moghra Formation of Egypt (Said 1962).

The age evidence from the vertebrates must await detailed work on the mammals, but provisional estimates are possible. There are two regions where comparisons can be made, East Africa and France. While there are other sites with similar faunas, they are of no help in dating since they are only aged by comparison with western Europe or East Africa. The East African succession of Miocene mammals, mainly from sites around the north-east corner of Lake Victoria, comprises a sequence of faunas in tuffaceous deposits which have been radiometrically dated. Several species in the East African faunas are also found in Gebel Zelten; these include *Mastodon angustidens*, *Prodeinotherium hobleyi*, *Diamantohyus africanus*, *Hyoboa africanus*, *Brachyodus*, *Listriodon*, *Aceratherium* and *Brachypotherium*. This strong similarity at specific and generic level suggests near contemporaneity. The closest comparisons are with Karungu (Kisingiri) and Bukwa (Mt. Elgon), both of which sites have been dated around 22.5 million years, which equates with early Burdigalian (Bishop et al. 1969).

In France mammal faunas are to be found in or near type sections and the mammals from the Burdigalian in the Aquitaine basin include *Mastodon angustidens*, *Deinotherium cuvieri* (very similar to *Prodeinotherium hobleyi*), *Listriodon lockharti* and *Brachyodus onoideus*. *Mastodon* appears for the first time in mid Burdigalian sites and *Deinotherium* appears in late Burdigalian; these are the earliest records of

proboscideans outside Africa. The close similarity of genera and species between France and Libya suggests closely comparable ages for the faunas. Allowing time for migration of species, it would be justifiable to suggest that the Gebel Zelten fauna is slightly earlier than the mid and late Burdigalian faunas of France, and so the conclusion that the Gebel Zelten fauna is early Burdigalian seems justifiable.

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